

TIME ALLOCATION IN CONCURRENT SCHEDULES: THE EFFECT OF SIGNALLED REINFORCEMENT¹

HENRY MARCUCELLA AND GARRY MARGOLIUS

BOSTON UNIVERSITY

The responses of five pigeons were reinforced on concurrent variable-interval variable-interval reinforcement schedules in which changeover key responses changed the stimulus and reinforcement schedules associated with the food key. While the reinforcement availability in one component remained unchanged throughout the experiment, the reinforcement availability in the other component was, during several conditions, signalled by the onset of an additional discriminative stimulus. During unsignalled conditions, both the relative frequency of responding and the relative time spent in each component approximated the obtained relative reinforcement frequency in each component. The effect of signalling reinforcer availability in one component was to (1) reduce responding in the signalled component to near-zero levels, and (2) increase the relative time in the unsignalled component, without a corresponding increase in the obtained relative reinforcement frequency. The magnitude of the increase in relative time in the unsignalled component decreased as the overall frequency of reinforcement increased. This deviation in the matching relation between relative time and the obtained relative reinforcement frequency was eliminated if the overall reinforcement frequency was increased before the signal was introduced and then, without removing the signal, gradually reduced.

Key words: matching, signalled reinforcement, time allocation, fixed-ratio changeover requirement, concurrent schedules, key peck, pigeons

In 1961, Herrnstein described a simple but predictive relationship between responses and reinforcement. Applied to performance on concurrent schedules, this rule states that the pigeon distributes its pecks such that the relative frequency of responding on one key matches the relative frequency of reinforcement on that key. Catania (1963) replicated and extended these findings to a variation of the concurrent procedure described by Findley (1958). In this paradigm, responses on one key (schedule key) were reinforced on different variable-interval (VI) schedules of reinforcement in the presence of different discriminative stimuli. Responses on the second key (changeover key) simply changed the discriminative stimulus and the reinforcement sched-

ules associated with the food key. A useful feature of the Findley method is that it allows the experimenter to assess time as well as response allocation to the two schedules. With this method, Catania (1966) further extended Herrnstein's findings by demonstrating that pigeons also matched the relative time spent in a component to the relative frequency of reinforcement obtained in that component.

Brownstein and Pliskoff (1968) suggested that the approximation of the relative response frequency to the relative reinforcement frequency may be a consequence of the relationship between relative time and relative reinforcement frequency. That is, if one assumes that the pigeon pecks on the schedule key at a constant rate, then the relative frequency of responding in a given component will match the relative reinforcement frequency of that component if the relative time spent in the component matches the relative reinforcement frequency.

Brownstein and Pliskoff (1968), Baum and Rachlin (1969), and Brownstein (1971) provided evidence that supported the interpretation of matching as a law of time allocation by demonstrating that the relative time in a

¹This research was supported in part by Boston University Graduate School Grant #381-PS. Portions of the paper were presented at the convention of the Psychonomic Society in Denver, Colorado in 1975 and at the convention of the American Psychological Association in San Francisco, California in 1977. The authors wish to thank Charles Abramson for his help in data collection. Reprints may be obtained from Henry Marcucella, Department of Psychology, Boston University, 64 Cummington Street, Boston, Massachusetts 02215.

component matched the relative reinforcement frequency of that component, even in the absence of pecking for reinforcement. The Brownstein and Pliskoff study used a procedure similar to the standard Findley procedure, except that the changeover key was the only response key available. A response on the changeover key changed the color of the chamber illumination and its associated schedule of reinforcement. While each color was in effect, reinforcers were delivered independently of the bird's behavior according to a variable-time (VT) schedule associated with each color.

If a law of time allocation, rather than a law of response distribution, governs behavior when responses are reinforced on *conc VI VI* schedules, then reducing or eliminating responding in one component of the schedule, without altering the relative reinforcement frequency should not disrupt the matching relation between relative time and relative reinforcement frequency. Thus, although responding in one component of a *conc VI VI* schedule is nearly eliminated, pigeons should still allocate time to each component on the basis of the relative frequency of reinforcement in each component.

The response rate in one component of a *conc VI VI* schedule can be reduced, without altering the obtained reinforcement frequency in that component, by signalling reinforcer availability (Brownstein and Newsom, 1970; Marcucella, 1976; Wilkie, 1973). In a signalled VI schedule, the onset of an additional discriminative stimulus signals the availability of each reinforcer, while the stimulus previously correlated with the VI schedule signals an extinction interval of variable duration. However, Wilkie (1973) reported that, when the response rate in one component of a *conc VI VI* schedule was reduced by signalling reinforcer availability, pigeons spent more time in the unsignalled component than would be expected according to a time matching law.

The present experiment first extended Wilkie's (1973) findings to situations in which a changeover response requirement was used and overall reinforcement frequency was held constant. The present experiment then demonstrated that (1) the magnitude of the preference for the unsignalled component decreased as the overall reinforcement frequency was increased, and (2) the manner in which the signal was introduced affected preference. The

results suggested that the deviation from a time matching law, produced by the abrupt introduction of an extinction-correlated stimulus (Marcucella, 1976), is a contrast-related phenomenon and not an indication of a fixed preference for unsignalled reinforcement.

METHOD

Subjects

Five male Silver King pigeons were maintained at 80% of their free-feeding weights. Water was available only in the home cage. Birds 1290, 3759, and 2612 were experimentally naive. Birds 2743 and 3894 had preliminary exposure to similar signalled *conc VI VI* schedules.

Apparatus

The experimental apparatus was a standard pigeon test chamber (Gerbrands Model #G6510) containing two clear-plastic response keys. Pecks of at least 0.15 N, on either key, were recorded and operated a feedback relay mounted behind the front panel. The reinforcer was 4-sec access to mixed grain delivered by a food hopper located below and between the two keys. Light from an Industrial Electronics Engineers projector transilluminated the keys. The houselight remained off during the session, but was illuminated at the end of the session. During reinforcement cycles, both keylights were turned off and the food hopper was illuminated. Masking noise was provided by a white-noise generator and an exhaust fan. Solid-state programming and recording equipment was located in an adjacent room.

Procedure

In a two-key chamber, the left key (schedule key) was either red (S1) or green (S2), with different VI schedules associated with each component. Both VI timers continued to operate during changeovers. Each VI schedule consisted of a series of 20 interreinforcement intervals, the values of which were derived from Catania and Reynolds (1968). A sequence of either 10 (Birds 1290, 2743, 3759, and 3894) or seven (Bird 2612) responses on the right key (changeover key) changed the color and the VI schedule associated with the schedule key. The first changeover response (COR) darkened the schedule key, and either the seventh (2612) or tenth illuminated the schedule key with the

alternative color. The changeover key was illuminated with a vertical line on a white background, except for 0.75 sec following completion of the changeover response requirement. On these occasions it was darkened in order to reduce the possibility that the pigeon would emit a sequence of more than the required number of changeover responses before pecking the schedule key.

In some phases of the experiment, reinforcer availability was signalled during the presence of the component associated with the red stimulus by changing the schedule key color from red to blue. If a reinforcer became available in the signalled component (S1) while the unsignalled component (S2) was in effect, the onset of the signal immediately followed completion of the changeover ratio. The signal remained on until a response occurred. After reinforcer delivery, the key color returned to red. Thus, all signalled component reinforcers were obtained when the key was blue and red signalled extinction. Pigeons 2743, 3759, and 3894 were also exposed to one signalled condition in which blackout (BO) replaced the red keylight. These data have been included in the appendix but will not be discussed.

Table 1
Summary of Experimental Conditions

Condi- tion	Schedule in S1 (in seconds)	Schedule in S2 (in seconds)	Sched- uled Overall Reinforce- ment Fre- quency (per minute)	Relative Reinforce- ment Fre- quency in S2
a	VI 15	VI 15	8.00	0.50
b	VI 15	VI 30	6.00	0.33
c	VI 15	VI 60	5.00	0.20
d	VI 30	VI 15	6.00	0.67
e	VI 30	VI 30	4.00	0.50
f	VI 60	VI 30	3.00	0.67
g	VI 60	VI 60	2.00	0.50
h	VI 60	VI 180	1.40	0.25
i	VI 90	VI 90	1.40	0.50
j	VI 120	VI 120	1.00	0.50
k	VI 120	VI 240	0.67	0.25
l	VI 180	VI 30	2.33	0.86
m	VI 180	VI 60	1.40	0.75
n	VI 180	VI 240	0.50	0.33
o	VI 180	VI 180	0.67	0.50
p	VI 240	VI 30	2.17	0.92
q	VI 240	VI 120	0.67	0.75
r	VI 240	VI 240	0.33	0.50

The COR requirement (Guilkey, Shull, and Brownstein, 1975) was used to prevent component bias. If the more-usual changeover delay (COD) procedure (Wilkie, 1973) were used, one would either have to allow unreinforced responses to occur in the presence of the signal during the COD or else prevent the onset of the signal until the COD had elapsed. Both alternatives increase the amount of time spent in the signalled component.

For similar reasons, reinforcer availability in each component was scheduled independently of reinforcer availability in the other component. That is, if a reinforcer had become available in S2 while the subject was responding in S1, it did not prevent additional reinforcers from becoming available in S1.

The variable-interval schedules studied averaged 240, 180, 120, 90, 60, 30, and 15 sec. Table 1 shows the schedules studied. The order in which each pigeon was exposed to the schedules in Table 1 and the number of sessions at each condition are included in the Appendix. Each session was terminated after delivery of 60 reinforcers (4-sec access to mixed grain).

With few exceptions, the signalled condition was introduced only after stable performance had been obtained on the baseline unsignalled schedule. Thus, a change in the relative and overall frequency of reinforcement was usually made during unsignalled conditions. However, in order to examine the effect of manipulating reinforcement frequency on stable signalled performance, four subjects were exposed to a sequence of conditions in which signalled conditions did directly follow other signalled conditions (see Appendix). Bird 3894 became ill after Condition 15 and was removed from the experiment; Bird 2612 replaced it. For this new bird, the signal was introduced immediately following acquisition of responding on *conc* VI 15-sec VI 15-sec. The COR requirement was gradually increased to seven responses after the signal was introduced.

RESULTS

The mean session data, for each pigeon, for the last five days of each condition, for all conditions, in order of presentation are presented in the Appendix.

Figure 1 shows both the relative response frequency (top) and the relative time (bottom) in the unsignalled component (S2) as a function of the obtained relative reinforcement frequency in S2. To facilitate comparisons, only those signalled and unsignalled conditions in which the overall reinforcement frequency was equal to 1.4 reinforcers per minute have been included in Figure 1. For unsignalled conditions, both relative response frequency and the relative time in S2 matched the relative reinforcement frequency fairly accurately. The equations of the best-fitting lines by the method of least squares are included in Figure 1 for each animal.

Signalling reinforcer availability in S1, in agreement with Wilkie (1973), influenced both the relative time and relative response frequency in S2. With one exception (Bird 3894), relative response frequency in S2 increased to levels near 1.0. That is, during signalled conditions, the number of responses in S1 emitted in red alone decreased to near-zero levels at

relative reinforcement frequencies of 0.75 and 0.50. The effect was not quite as strong at a relative reinforcement frequency of 0.25. As the reinforcement frequency increased in the presence of S1 and decreased in the presence of S2, the frequency of unreinforced S1 responses increased.

The effect of signalling reinforcer availability on the relative time in S2 was considerably different. Although adding the signal also increased the relative time spent in S2, the magnitude of the change was much less than that observed in the relative response frequency. This result was primarily due to the animals spending considerable time in S1 without pecking the key; that is, after pigeons changed over to the signalled component, they remained in that component, even though the signal was not present and the extinction-correlated stimulus was in effect. Figure 1 also shows that the obtained relative reinforcement frequency in S2 approximated the scheduled relative reinforcement frequency and re-

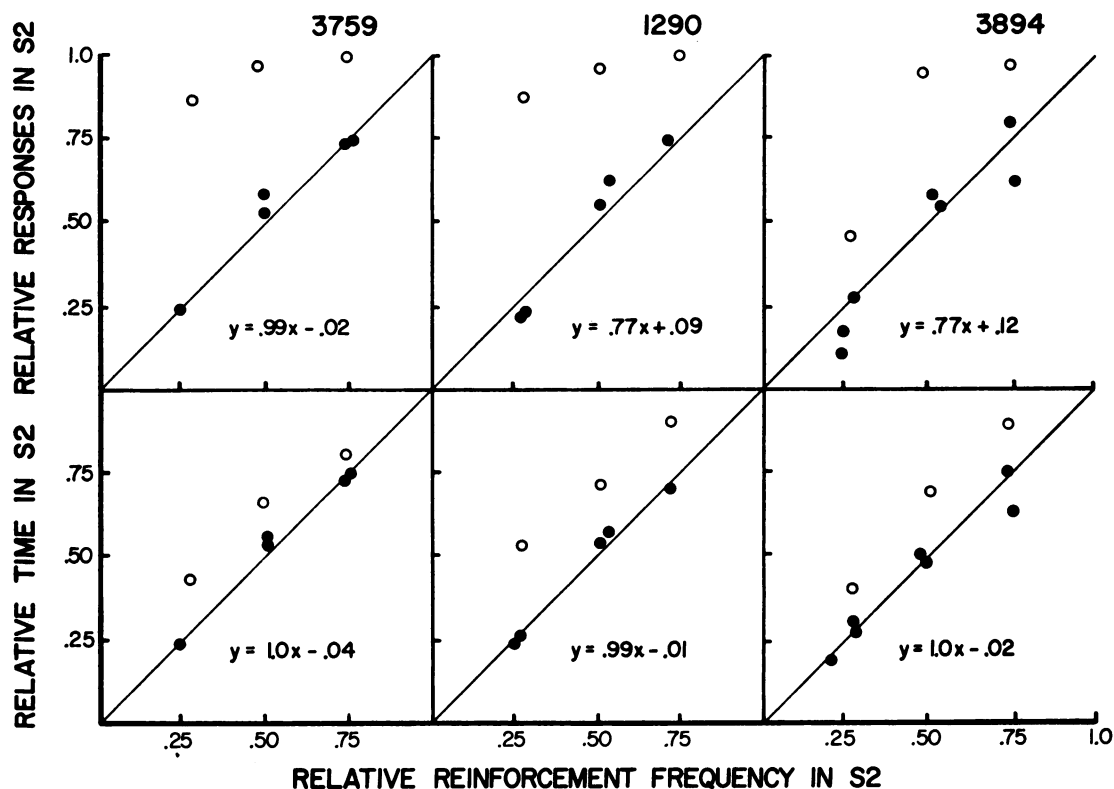


Fig. 1. The relative response frequency (top) and relative time in the unsignalled component as a function of the obtained relative reinforcement frequency in S2 for unsignalled (closed circles) and signalled (open circles) conditions. Each data point represents the average of the last five sessions of each condition. Overall reinforcement frequency was constant at 1.4 reinforcers per minute.

mained relatively constant during both the signalled and unsignalled conditions.

Figure 2 shows the relative local response rate in S2 as a function of the obtained relative reinforcement frequency in S2. Relative local response rate was calculated by dividing the local rate in S2 by the sum of the local rates in S1 and S2. Data are provided for only those unsignalled conditions presented in Figure 1. For Bird 3759, relative local response rate reasonably approximated 0.50 over all relative reinforcement frequencies tested. However, for Birds 1290 and 3894, the local response rate was slightly below 0.50 at a relative reinforcement frequency of 0.25 and slightly above 0.50 at a relative reinforcement frequency of 0.75. Two of the three birds tended to peck at a higher rate in the presence of the component stimulus associated with the higher reinforcement frequency.

Figure 3 shows the per cent change in both the relative proportion of time spent in S2 (closed circles) and the relative reinforcement frequency in S2 (open circles) produced by signalling reinforcer availability, as a function of overall reinforcement frequency (reinforcers per minute). Data are presented only for those conditions in which the relative reinforcement frequency equalled 0.50. The change in relative time in S2 was calculated by subtracting the average relative time in S2 for the last five sessions of the unsignalled condition from the average relative time in S2 for the last five sessions of the corresponding signalled condition. The per cent change in relative reinforcement frequency was calculated in a similar fashion. The signalled conditions immediately followed the unsignalled conditions.

Figure 3 shows that as the overall frequency of reinforcement of the baseline unsignalled schedule was increased, the magnitude of the change in relative time in S2, produced by signalling reinforcer availability, decreased. In contrast, the addition of the signal had very little effect on the obtained relative reinforcement frequency at any overall frequency tested; relative reinforcement frequency approximated 0.50 during both signalled and unsignalled conditions. Thus, Figure 3 demonstrates that as the overall frequency of reinforcement increased, the magnitude of the deviation from matching produced by the signal decreased to zero or near-zero levels. That is, even though responding in the sig-

nalled component was nearly eliminated, pigeons continued to allocate time to the signalled component according to the relative reinforcement frequency in that component. The decrease in relative time in S2 cannot be simply attributed to repeated introductions of the signal, for each pigeon was exposed to a different sequence of schedules (Appendix).

The previous analysis demonstrated that the smallest deviation from the matching relation between relative time and relative reinforcement frequency was obtained when the signal was added to one component of a *conc VI VI* schedule in which the overall reinforcement frequency was greater than four reinforcers per minute. Birds 1290, 2743, 3759, and 2612 were exposed to a sequence of signalled conditions (Conditions 24 to 28 for Bird 1290, 13 to 16 for 2743, 16 to 21 for 3759, and 1 to 3 for 2612) to examine whether the slight deviation obtained at the denser reinforcement frequencies would change if either the reinforcement schedule in one (Birds 3759 and

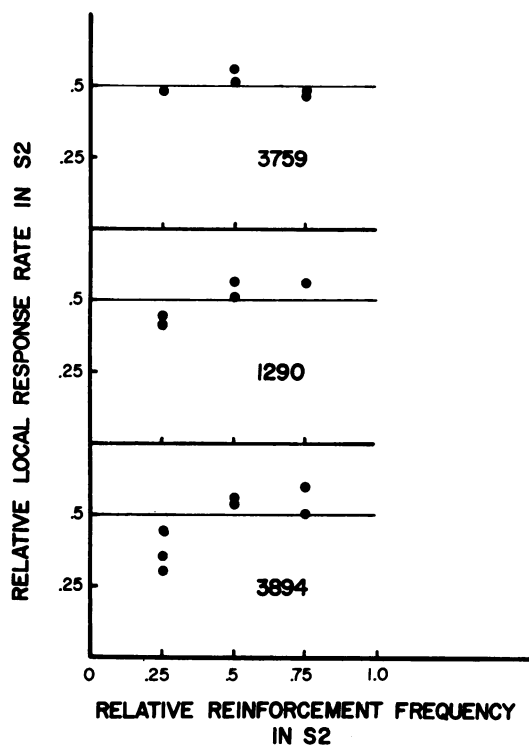


Fig. 2. Relative local response rate in S2 as a function of the relative reinforcement frequency in S2. Data are provided for those unsignalled conditions presented in Figure 1.

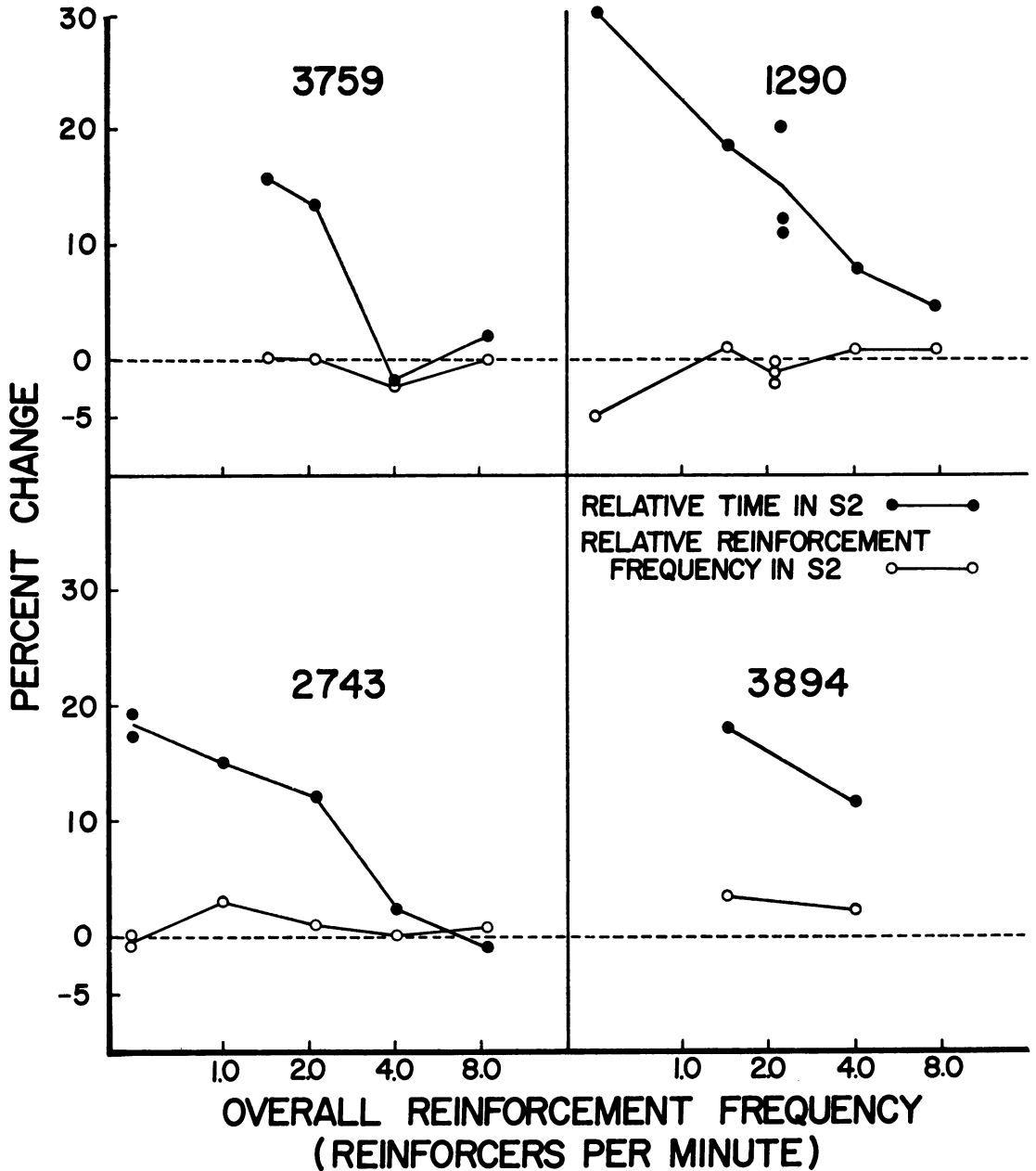


Fig. 3. The per cent change produced by introduction of the signal in relative time in S2 (closed circles) and relative reinforcement frequency in S2 (open circles) as a function of overall reinforcement frequency. Relative reinforcement frequency was constant at 0.5.

2612) or both components (2743 and 1290) were changed without removing the signal.

Figure 4 shows the relative response frequency (closed circles), relative time (open circles), and the obtained relative reinforcement frequency (dashed lines) in S2 for each session as a function of these schedule changes.

The sequence of schedules associated with S1 and S2, respectively, are shown in each panel of Figure 4. For Birds 3759 and 2743, only the last five sessions of baseline *conc* VI 30-sec signalled VI 30-sec, and for Birds 1290 and 2612 only the last five sessions of baseline VI 15-sec signalled VI 15-sec are presented. Due to an

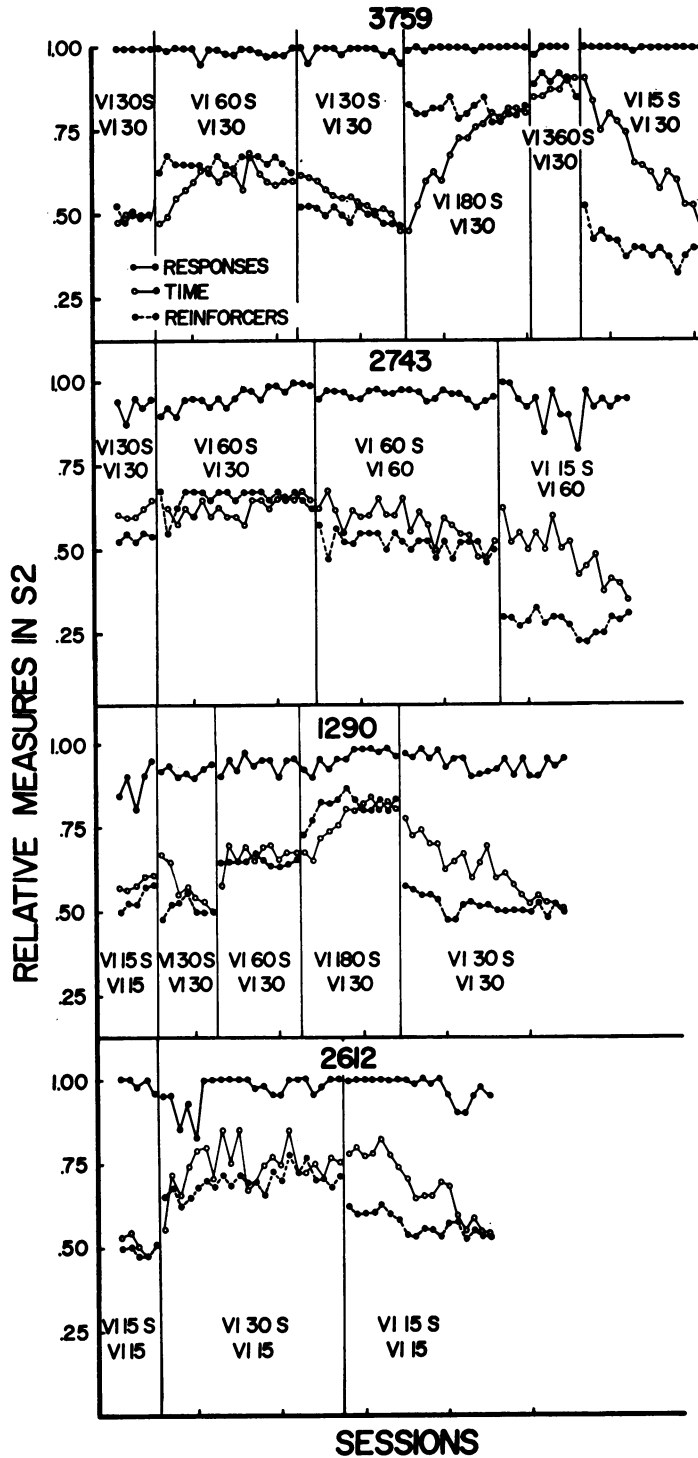


Fig. 4. The relative response frequency (closed circles), relative time (open circles), and relative reinforcement frequency (dashed lines) in S2 per session for signalled conditions in which the reinforcement frequency in S1 (Birds 3759 and 2612) or S1 plus S2 (Birds 2743 and 1290) was changed without first returning to the corresponding baseline unsignalled concurrent schedules.

equipment failure, the last condition for Birds 3759 and 2743 had to be terminated prematurely.

The data in the first panel of Figure 4 show that, for all birds, relative time in S2 closely approximated the relative frequency of reinforcement in S2. Changing the reinforcement schedule in one component without removing the signal resulted in an abrupt change in the obtained reinforcement frequency, so that it matched the new scheduled relative reinforcement frequency. Within a few sessions, the relative time in S2 also changed, until it again approximated the obtained relative reinforcement frequency. That is, relative time in S2 changed, as the obtained relative reinforcement frequency in S2 changed, so that a matching relationship continued to occur. For Bird 2743, matching was obtained when the overall reinforcement frequency was decreased to levels at which the abrupt introduction of the signal had previously produced a substantial deviation from matching; e.g., *conc* VI 60-sec signalled VI 60-sec.

It is important to note that the performance of 2612 was similar to that of the other subjects, even though it had not been previously exposed to other *conc* VI signalled VI schedules. In addition, the data of Bird 2612 provide additional evidence that the relationship between the per cent change in relative time in S2 and overall reinforcement frequency shown in Figure 3 is not due simply to repeated introductions of the signal. For Bird 2612, introduction of the signal to one component of *conc* VI 15-sec VI 15-sec (Panel 1, Figure 4) did not produce a deviation from matching, even though it was the bird's first exposure to the signal.

DISCUSSION

The present results partially support the time-allocation hypothesis. The effect of signalling reinforcer availability, in one of the concurrent VI schedules, on the matching relationship between obtained relative reinforcement frequency and relative time in each component, was a function of the manner in which the signal was introduced. When the signal was introduced at high overall reinforcement frequencies, its disruptive effect on the matching relation obtained during the unsignalled

baseline conditions (Figure 3) was minimized. Furthermore, the relative time continued to match the obtained relative reinforcement frequency, even when the reinforcement schedule in one or both components was subsequently changed. Thus, the data of Figure 4 support the suggestion of Brownstein and Pliskoff (1968) and Baum and Rachlin (1969) that a law of time allocation, rather than a law of response distribution (Herrnstein, 1961), governs behavior maintained on concurrent VI schedules of reinforcement.

However, the results of abruptly introducing the signal at low overall reinforcement frequencies did not always support the time-allocation law. At reinforcement frequencies ≤ 4.0 reinforcers per minute, the relative time spent in the unsignalled component (S2) increased, even though the obtained relative reinforcement frequency remained constant. The present study also demonstrated that, with identical VI schedules associated with each component, the magnitude of this deviation from matching was inversely related to the obtained overall reinforcement frequency.

One possible explanation of this deviation from the matching relation could be that pigeons prefer unsignalled reinforcement (Wilkie, 1973). Such a preference would appear to increase as the overall reinforcement frequency decreases. However, the preference explanation does not account for the role of the procedure used to introduce the signal. Figure 3 shows that abruptly adding the signal to a *conc* VI 60-sec VI 60-sec schedule resulted in a substantial increase in the relative time allocated to the unsignalled component, with no corresponding increase in the obtained relative reinforcement frequency. Thus, there was a substantial deviation from the matching relation. The data of Figure 4 (Bird 2743) show, however, that this deviation from matching did not occur when the reinforcement schedule was changed to *conc* VI 60-sec signalled VI 60-sec after the signal was first added to a *conc* VI 30-sec VI 30-sec schedule.

An alternative explanation of this deviation from matching considers both the frequency of signal presentations and the presence of an extinction-correlated stimulus in the signalled component. These variables may have influenced time allocation during the transition from unsignalled to signalled performance. As the signal began to exert control over

responding in the signalled component, the stimulus previously associated with that component (red) began to signal extinction. As a result, the pigeon's behavior began to resemble performances observed when pigeons' responses are reinforced on *conc VI EXT* schedules (Catania, 1966). They changed over to the unsignalled component and allocated more time to that component. However, since the addition of the signal did not alter the scheduling of reinforcement in the signalled component, the pigeons were occasionally rewarded for changing over to the signalled component. Although most changeover responses were followed by the onset of the extinction stimulus (red), which set the occasion for immediately changing back to the unsignalled component, a few changeover sequences were immediately followed by onset of the signal. As a result, the pigeons continued to change over to the signalled component, although they did not remain in that component long enough for matching to occur. At the same time, since the signal was reinforcing, its frequency opposed this shift in relative time to the unsignalled component. The pigeons were rewarded by onset of the signal, not only for changing over to the signalled component, but also for remaining in the presence of the extinction stimulus.

According to this analysis, the magnitude of the deviation from matching, although limited by the obtained relative reinforcement frequency, was the result of the dynamic interplay of extinction and signal frequency. While extinction was acting to increase the relative time allocated to the unsignalled component, signal frequency was simultaneously acting to increase the amount of time allocated to the signalled component. The relative strength of these two variables depended on the reinforcement frequency in the signalled component. At low reinforcement frequencies, few signals were presented, and the probability that an animal would be rewarded for remaining in extinction was low. Therefore, low signal frequencies did little to oppose the shift to the nonsignalled component, and a large increase in the relative time in S2 was obtained. At higher reinforcement frequencies, the probability of being reinforced while in the signalled component was greater, and this effect more strongly opposed the tendency to allocate time to the unsignalled component.

The data of Figure 4 are also consistent with the present hypothesis. The sequence of signalled schedules described there can be viewed as a shaping procedure that minimized the effect of introducing an extinction stimulus. Because at high reinforcement frequencies (four to eight reinforcers per minute) remaining in the presence of the extinction stimulus was often reinforced, it quickly increased in duration until the relative time in S2 approximated the obtained relative reinforcement frequency in S2. Once this waiting response was established, it was maintained even when reinforcement frequency was gradually reduced.

In summary, the present results question the utility of using *conc VI VI* schedules to examine whether animals demonstrate a preference for signalled *versus* unsignalled reinforcement conditions. Preference for the unsignalled component of a *conc VI VI* schedule, easily eliminated by altering the manner in which the signal was introduced, appeared to be a contrast-related phenomenon produced by different variables than the preference for signalled conditions reported by several earlier researchers (Badia and Culbertson, 1972; Badia, Culbertson, and Lewis, 1971; Lutz and Perkins, 1960; Lewis, Lewin, Muehleisen, and Stoyak, 1975; Prokasy, 1956).

REFERENCES

- Badia, P. and Culbertson, S. The relative aversiveness of signalled *vs.* unsignalled escapable and inescapable shock. *Journal of the Experimental Analysis of Behavior*, 1972, 17, 463-471.
- Badia, P., Culbertson, S., and Lewis, P. The relative aversiveness of signalled *vs.* unsignalled avoidance. *Journal of the Experimental Analysis of Behavior*, 1971, 16, 113-121.
- Baum, W. M. and Rachlin, H. C. Choice as time allocation. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 861-874.
- Brownstein, A. J. Concurrent schedules of response-independent reinforcement: duration of a reinforcing stimulus. *Journal of the Experimental Analysis of Behavior*, 1971, 15, 211-214.
- Brownstein, A. J. and Newson, C. Behavioral contrast in multiple schedules with equal reinforcement rates. *Psychonomic Science*, 1970, 18, 25-26.
- Brownstein, A. J. and Pliskoff, S. S. Some effects of relative reinforcement rate and changeover delay in response-independent concurrent schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 683-688.
- Catania, A. C. Concurrent performances: reinforcement interaction and response independence. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 253-263.

- Catania, A. C. Concurrent operants. In W. K. Honig (Ed), *Operant behavior: areas of research and application*. New York: Appleton-Century, Crofts, 1966. Pp. 213-270.
- Catania, A. C. and Reynolds, G. S. A quantitative analysis of the responding maintained by interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 327-383.
- Findley, J. D. Preference and switching under concurrent scheduling. *Journal of the Experimental Analysis of Behavior*, 1958, 1, 123-144.
- Guilkey, M., Schull, R. L., and Brownstein, A. J. Response rate invariance in concurrent schedules: effects of different changeover contingencies. *Journal of the Experimental Analysis of Behavior*, 1975, 24, 43-52.
- Herrnstein, R. J. Relative and absolute strength of response as a function of frequency of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1961, 4, 267-272.
- Lewis, P., Lewin, L., Muehleisen, P., and Stoyak, M. Preference for signalled reinforcement. *Journal of the Experimental Analysis of Behavior*, 1974, 22, 143-150.
- Lutz, R. F. and Perkins, C. C. Jr. A time variable in the acquisition of observing responses. *Journal of Comparative and Physiological Psychology*, 1960, 53, 180-182.
- Marcucella, H. Signalled reinforcement and multiple schedules. *Journal of the Experimental Analysis of Behavior*, 1976, 26, 199-206.
- Prokasy, W. F. Jr. The acquisition of observing responses in the absence of differential external reinforcement. *Journal of Comparative and Physiological Psychology*, 1956, 49, 131-134.
- Wilkie, D. M. Signalled reinforcement in multiple and concurrent schedules. *Journal of the Experimental Analysis of Behavior*, 1973, 20, 29-36.

Received 15 June 1977.

(Final acceptance 19 October 1977.)

APPENDIX

Data for individual birds. See Table 1 for the schedules that correspond to each lettered condition listed in Column 2. The symbol "S" designates that the availability of S1 reinforcers was signalled; "BO" refers to sessions in which the red stimulus was changed to black-out. All data are means of the last five days of exposure to each condition. Column 3 lists the number of sessions at each condition; Column 4, the mean number of unreinforced responses in red; Column 5, the time in red; Column 6, the unreinforced responses in green; Column 7, the time in green; Column 8, reinforcers in green (S2). The number of reinforcers obtained in S1 can be calculated by subtracting the number of reinforcers in green from 60. The total number of responses in S1 or S2 equals the number of unreinforced responses plus the number of reinforcers. For example, in S2, the total number of responses equals the number of green responses plus the number of green reinforcers. Column 9 lists the number of changeover sequences; Column 10, changeover time per session; and Column

11, time in signal per session. For signalled conditions, time in S1 equals the time in red plus the time in the signal.

For Bird 1290, standard deviations for the means in Column 4 ranged from 2.0 to 303.0; in Column 5, from 0.2 to 4.2; in Column 6, from 3.2 to 282.2; and in Column 7, from 0.3 to 3.9. For Bird 2743, standard deviations for the means in Column 4 ranged from 0.0 to 141.0; in Column 5, from 0.3 to 4.3; in Column 6, from 5.2 to 297.0; and in Column 7, from 0.3 to 4.7. For Bird 3759, standard deviations for the means in Column 4 ranged from 1.3 to 195.0; in Column 5, from 0.2 to 3.2; in Column 6, from 16.0 to 303.0; and in Column 7, from 0.1 to 1.7. For Bird 3894, the standard deviations for the means in Column 4 ranged from 0.0 to 126.0; in Column 5, from 0.1 to 1.5; in Column 6, from 12.0 to 61.0; and in Column 7, from 0.2 to 2.4. For Bird 2612, the standard deviations for the means in Column 4 ranged from 0.9 to 14.4; in Column 5, from 0.1 to 0.3; in Column 6, from 4.8 to 48.0; and in Column 7, from 0.0 to 0.8.

Bird 1290

Condition	Sched- ule	Ses- sions	Response Red	Time Red (min)	Response Green	Time Green (min)	Rein- force- ments Green	Change- overs	Time (min) Change- over	Time Signal (min)
1	g	34	665	11.5	378	10.5	29	179	5.6	—
2	g S	36	20	5.8	609	14.4	27	293	5.3	0.68
3	g	13	524	10.6	544	12.5	29	244	4.4	—
4	h	15	1596	25.7	490	11.0	17	311	5.6	—
5	h S	36	91	15.4	688	19.0	16	411	8.6	0.93
6	h	18	1062	27.1	321	10.1	16	258	6.1	—
7	m	26	310	10.9	904	24.5	43	285	7.0	—
8	m S	17	15	3.1	1408	33.8	44	228	5.8	0.39
9	q S	7	25	6.8	2824	72.5	45	310	8.4	0.43
10	r	12	1908	62.6	2524	80.0	32	823	23.8	—
11	r S	16	103	20.2	6492	123.0	28	724	21.9	0.99
12	r	15	3023	64.3	3972	82.2	31	757	25.2	—
13	g	6	1009	12.3	995	13.1	31	183	5.1	—
14	g S	38	41	8.4	847	14.1	29	259	5.2	0.99
15	g	17	695	10.2	840	12.1	31	200	4.8	—
16	g S	38	70	6.7	689	14.2	31	235	4.9	0.67
17	g	11	622	11.0	826	12.9	31	196	4.4	—
18	i	14	851	15.2	1124	18.7	31	266	6.9	—
19	i S	32	87	9.3	1688	26.1	32	239	6.4	0.88
20	i	22	776	14.3	1442	20.1	31	249	6.0	—
21	e	10	328	5.4	379	6.2	31	111	2.3	—
22	e S	37	39	4.7	374	9.2	32	66	1.5	0.77
23	a	38	109	3.1	144	3.8	31	43	1.6	—
24	a S	48	19	2.4	152	4.7	32	42	1.2	0.60
25	e S	7	37	4.0	378	6.2	31	75	2.1	0.80
26	f S	10	34	4.8	518	11.2	40	95	2.3	0.40
27	l S	12	26	3.5	988	16.8	49	73	1.7	0.24
28	e S	20	30	4.9	330	6.2	30	81	1.8	0.75

Bird 2743

Condition	Sched- ule	Ses- sions	Response Red	Time Red (min)	Response Green	Time Green (min)	Rein- force- ments Green	Change- overs	Time (min) Change- over	Time Signal (min)
1	g	10	310	9.7	337	12.5	29	153	5.6	—
2	g S	30	15	6.7	495	16.1	30	195	6.4	0.72
3	g	8	342	11.6	367	12.0	32	210	6.5	—
4	j	21	807	24.5	837	24.7	29	262	12.2	—
5	j S	18	111	14.5	1197	29.3	31	371	13.7	0.65
6	j	25	604	18.5	826	24.9	29	356	13.4	—
7	r	7	1259	59.1	1833	81.7	31	712	28.3	—
8	r S	24	189	30.9	2661	93.9	30	801	29.2	0.77
9	r	33	1398	50.3	2031	70.4	30	955	35.2	—
10	r S	28	97	31.0	2488	106.1	30	969	36.1	0.74
11	n S	16	134	49.2	928	40.8	18	697	23.8	0.96
12	e	14	125	4.5	171	6.0	32	118	3.8	—
13	e S	43	14	4.1	184	6.6	32	103	3.7	0.53
14	f S	19	5	4.9	272	9.3	39	115	5.1	0.38
15	i S	22	16	10.2	304	10.8	30	134	6.1	0.58
16	c S	20	26	6.1	65	4.1	16	57	3.0	0.97
17	o	30	722	25.6	1193	34.6	31	352	2.4	—
18	o S BO	20	3	15.6	1333	34.3	30	444	2.5	0.64
19	o	41	638	23.7	1191	38.3	31	323	2.6	—
20	a	6	109	3.6	125	4.4	30	41	2.6	—
21	a S	9	59	2.9	103	4.1	31	37	2.3	0.54

Bird 3759

Condition	Sched- ule	Ses- sions	Response Red	Time Red (min)	Response Green	Time Green (min)	Rein- force- ments Green	Change- overs	Time (min) Change- over	Time Signal (min)
1	g	19	364	9.7	377	10.0	29	276	7.5	—
2	g S	22	12	6.3	373	11.0	29	322	8.9	0.49
3	g	10	550	10.0	411	8.4	28	303	7.3	—
4	m	23	385	10.0	1028	27.7	44	234	5.8	—
5	m S	20	12	6.3	943	28.8	44	273	6.9	0.26
6	m	16	281	9.6	588	27.3	44	255	6.8	—
7	h	40	857	27.1	297	10.1	16	240	6.4	—
8	h S	20	61	16.8	401	13.5	17	404	11.2	0.79
9	k	6	1527	57.9	474	18.5	15	404	10.3	—
10	k S	18	51	43.0	632	26.4	16	571	18.8	0.86
11	q S	30	20	11.9	1929	55.3	45	486	16.5	0.32
12	q	29	241	12.6	1457	63.1	46	243	7.0	—
13	e	10	188	5.2	210	5.1	31	132	4.2	—
14	e S	20	11	5.0	190	4.5	28	159	4.5	0.67
15	e S BO	7	0	5.2	182	5.1	29	152	4.4	0.83
16	e S	12	1	5.2	175	5.1	30	104	4.4	1.00
17	f S	17	5	5.1	370	7.9	39	176	5.3	0.75
18	e S	13	4	4.8	182	4.8	29	147	4.2	0.99
19	l S	15	1	3.7	812	14.8	48	182	5.0	0.40
20	p S	6	9	2.6	1345	18.7	54	145	4.5	0.20
21	b S	15	2	2.9	235	4.1	23	110	3.5	0.90
22	i	14	592	13.7	950	17.3	30	267	7.8	—
23	i S	29	25	10.1	755	22.2	30	280	8.6	0.82
24	i	12	697	15.1	893	17.5	30	331	9.6	—
25	a	7	157	3.6	232	4.7	33	33	2.3	—
26	a S	26	13	2.1	147	3.7	33	50	3.3	0.60

Bird 3894

Condition	Sched- ule	Ses- sions	Response Red	Time Red (min)	Response Green	Time Green (min)	Rein- force- ments Green	Change- overs	Time (min) Change- over	Time Signal (min)
1	g	6	853	13.1	698	12.4	29	85	3.0	—
2	h	27	2305	26.2	312	8.2	14	111	3.7	—
3	h S	34	570	24.1	727	16.8	16	187	4.3	0.90
4	h	32	2279	29.6	463	11.5	15	177	4.7	—
5	g	24	1490	16.5	677	11.0	30	105	3.0	—
6	m	44	1050	14.7	1910	26.1	45	150	5.2	—
7	m S	43	96	4.4	2505	34.1	45	418	4.2	0.36
8	m	10	461	8.6	2300	28.4	44	162	4.9	—
9	e	30	389	8.1	397	6.7	30	73	3.1	—
10	e S	27	674	5.8	333	8.6	31	56	2.6	0.56
11	e S BO	38	0	7.1	730	9.0	33	77	3.0	0.64
12	i	15	1182	16.6	1641	19.7	30	150	6.3	—
13	i S	31	159	9.7	2611	24.8	33	173	6.0	0.74
14	i	33	1309	17.3	1711	18.0	31	121	7.1	—
15	h	36	2248	28.0	796	12.3	16	93	4.6	—

Bird 2612

Condition	Sched- ule	Ses- sions	Response Red	Time Red (min)	Response Green	Time Green (min)	Rein- force- ments Green	Change- overs	Time (min) Change- over	Time Signal (min)
1	a S	20	1	1.5	49	2.3	29	89	3.4	0.6
2	d S	22	8	1.7	433	6.8	42	52	1.7	0.5
3	a S	18	26	2.2	284	3.6	32	54	1.7	0.4